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DETECTION OF LOW-LEVELS OF RADIOACTIVITY

Cossairt¹ has compared the response of the rotary-switch Elron survey meter with that of a 1" (diameter) by 1" NaI(Tl) Thyac detector. At the time of those measurements, the 1" by 1" Thyac probe was the standard Fermilab survey instrument for the detection of low-levels of γ -radioactivity. Currently, the Thyac with a 1 1/2" (diameter) by 1" probe has replaced this as the Fermilab standard.

This note gives results, similar to Cossairt's, of a comparison of the Elron, Ludlum survey meter, and Wallflower detectors with the 1 1/2" by 1" Thyac. The experiment was performed with the special source collimator and measuring table (shown in Fig. 1) in the IMAC lab on WH-7E by use of radioactive sources of different strengths and γ -ray energies. Care was exercised in the measurements to be sure that the solid angle of the source-detector system was determined by the geometric size of the instruments themselves at all distances. In Fig. 2, the calculated efficiency² of the 1 1/2" by 1" NaI(Tl) probe for the 661-keV ^{137}Cs γ -ray as a function of source-to-detector distance is compared with the same quantity determined from measured background-corrected Thyac counting rates for a 247- μCi ^{137}Cs source. The reasonably good agreement between the measurements (x's) and the calculations (solid curve) attest to the adequacy of the experimental arrangement.

The relative response of the rotary-switch Elron and the 1 1/2" by 1" NaI(Tl) Thyac probe are shown in Fig. 3 for ^{22}Na , ^{60}Co , and ^{137}Cs radioactive sources. The solid lines are straight-line fits to the source data for Thyac counting rates < 80,000 counts/min. (Because of saturation of the electronic circuitry the Thyac will underrespond at rates higher than this).³ The Elron response relative to that of the Thyac is different depending on the energy of the radiation field, and can be represented by the equations for the straight lines shown in Table 1. The last column in the Table explicitly gives the Elron response corresponding to a Thyac counting rate of 10,000 cpm for the three sources.

These latter results can be compared to the relative Elron-Thyac responses to the mixed-energy background radiation rates at eight locations around Fermilab, as shown⁴ in Table 2. For the Thyac, the background counting rate is reasonably well determined. For the Elron, however, the rates shown should be considered upper limits. Since the low Elron rates are based on very few events/min in the GM tube,¹ large fluctuations are expected in a background determination with this instrument. It is probably reasonable to expect the average background as measured with the Elron to be lower by as much as a factor of 2 from the value indicated in Table 2. With these points in mind, the results suggest that a Thyac rate of 10000 counts/min corresponds to an Elron response as low as ~ 0.05 mR/hr (with a large uncertainty), in approximate agreement with an average of the numbers in the first three rows of the last column of Table 1. Thus, a Thyac reading of "twice background" of an activated item (~ 4000 cpm) would correspond to an Elron rate of 0.02-0.025 mR/hr, which would be difficult

to distinguish from the background. On the other hand, an Elron reading of 0.04-0.05 mR/hr (8000-10000 cpm on a Thyac), represents a clear indication of low-level radioactivity.

The response of the Ludlum survey instrument and the Fermilab Wallflower detector, relative to the 1 1/2" by 1" Thyac are shown in Fig. 4 for ^{137}Cs sources. The equations of the straight line fits to the source data (again, only for Thyac rates < 80000 cpm) are shown in Table 1. As seen, the slopes of the curves for the three GM instruments (Elron, Ludlum, and Wallflower) are very similiar, at least when the Wallflower detector is used in its side-response configuration.

Finally, Fig. 5 shows a comparison between the responses of the 1 1/2" by 1" and 1" by 1" Thyac probes relative to that of the rotary-switch Elron for a ^{137}Cs source. The larger probe is clearly more sensitive (by a factor of two) for the detection of low-levels of γ -radioactivity. It is not clear why the smooth curve (labeled Ref. 1), based on a fit to the ^{137}Cs source data of Cossairt,¹ does not agree better with the 1" by 1" data in the present report. However, the experimental setup, particularly the method of source collimation, used in Ref. 1 was substantially different and more primitive from that of the present measurements, so that a considerably larger in-scattering contribution to the measured counting rates may have been included.

References

1. J. D. Cossairt, Radiation Physics Note 27, November 7, 1980.
2. J. H. Neiler and P. R. Bell, in Alpha-, Beta-, and Gamma-Ray Speetroscopy, ed. K. Siegbahn, Vol. 1 (North-Holland, Amsterdam, 1965) p. 245.
3. F. P. Krueger, private communication.
4. This data was obtained in collaboration with Chuck Zonick.

TABLE 1. Equations of the straight lines representing the G-M instrument responses relative to that of the 1 1/2" by 1" Thyac. The Elron (E), Ludlum (L), and Wallflower (W) responses (in mR/hr) are equal to the Thyac (T) reading (in counts/min) times the Slope, plus the Intercept.

Instrument	Source	E γ (MeV)	Slope (mR/hr)/cpm	Intercept (mR/hr)	Exposure Rate at 10000 cpm
E	^{137}Cs	0.661	$3.61(10^{-6})$	$-9.85(10^{-3})$.03 mR/hr
E	^{22}Na	0.511, 1.27	$4.25(10^{-6})$	$1.36(10^{-2})$.055 mR/hr
E	^{60}Co	1.17, 1.33	$9.31(10^{-6})$	$-3.35(10^{-2})$.06 mR/hr
L	^{137}Cs	0.661	$3.23(10^{-6})$	$-1.75(10^{-3})$.03 mR/hr
W(Side)	^{137}Cs	0.661	$3.59(10^{-6})$	$-9.81(10^{-3})$.03 mR/hr
W(Head-On)	^{137}Cs	0.661	$1.74(10^{-6})$	$2.26(10^{-2})$.04 mR/hr

TABLE 2. Relative response of Elron and 1 1/2" by 1" Thyac survey instruments to background radiation levels at various sites at Fermilab. (This data was obtained in collaboration with Chuck Zonick).

Area Surveyed	Thyac (cpm)	Elron (mR/hr) (upper limits)
Road A-2. Hi-Rise	1500	0.015
N1. Dumpster	2500	0.025
N1. Inside	2500	0.025
Proton Field Office	2300	0.02
TPL. Dumpster	2500	0.02
IB 1. Dumpster	2000	0.02
IB 1. Inside	1500	-
A0. Parking Lot	1750	0.015
<u>Average</u>	2069	<.02

Figure Captions

1. Schematic of the experimental arrangement.
2. Efficiency of the 1 1/2" (diameter) by 1" NaI(Tl) Thyac probe for the 661-keV γ -ray from ^{137}Cs as a function of source-detector distance. The solid curve is the calculated efficiency. The points are from background - corrected data.
3. The rotary-switch Elron response relative to the 1 1/2" by 1" Thyac for various radioactive sources measured at the same source-to-detector distances. The instrument counting rates have not been corrected for the background rate. The straight lines represent fits to the data for all points corresponding to Thyac counting rates < 80000 cpm.
4. The Ludlum and Wallflower responses relative to the 1 1/2" by 1" Thyac for ^{137}Cs sources measured at the same source-to-detector distances. The instrument counting rates have not been corrected for the background rate. The straight lines represent fits to the data for all points corresponding to Thyac counting rates less than 80000 cpm.
5. The Elron response relative to the responses of the 1" by 1" and 1 1/2" by 1" Thyac probes for a ^{137}Cs source measured at the same distances. The curve labeled Ref. 1 is based on a fit to the ^{137}Cs

source data in that reference. The other straight lines are fits to the data for all points corresponding to Thyac counting rates < 80000 cpm.

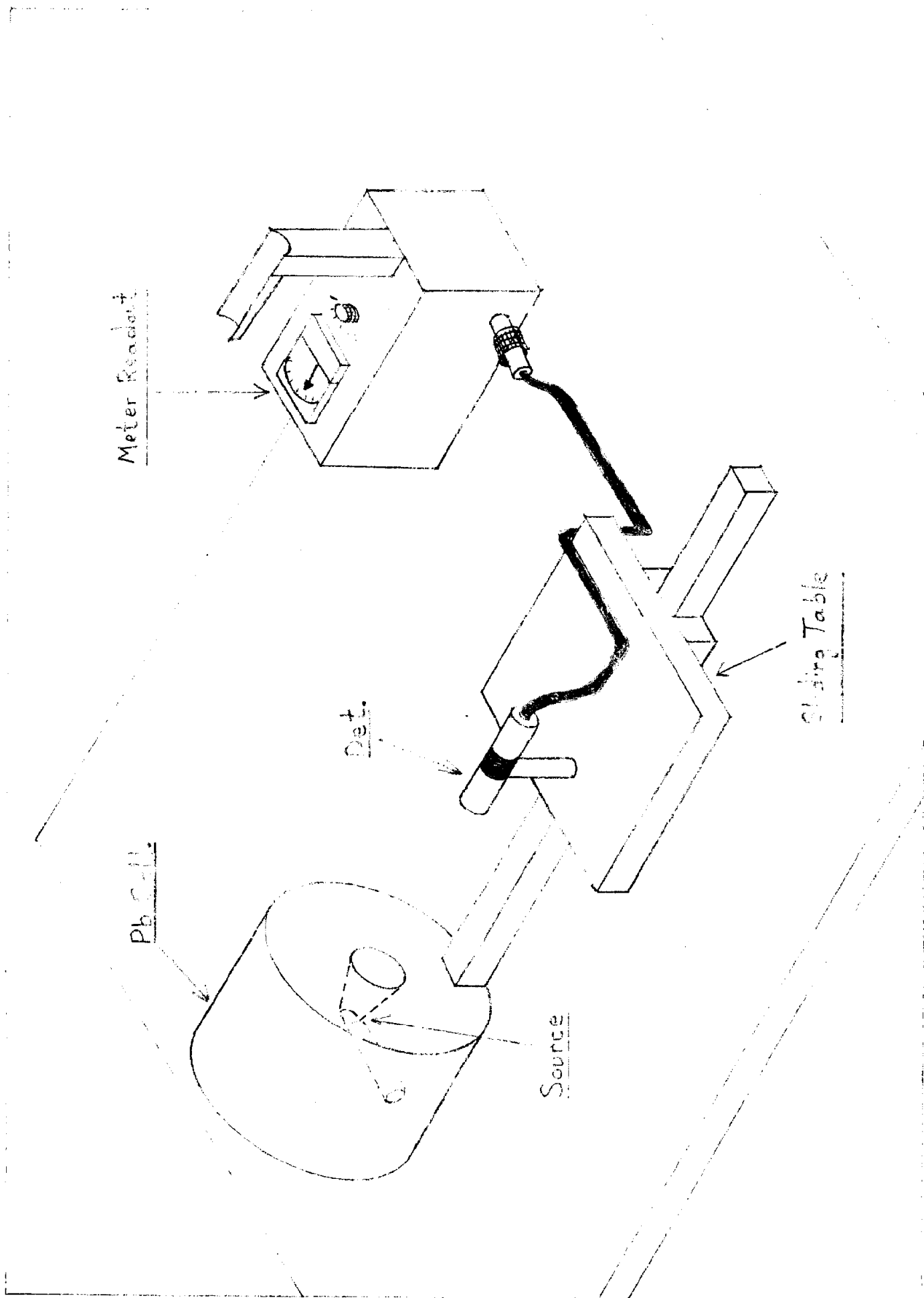


Figure 1

FIGURE 2

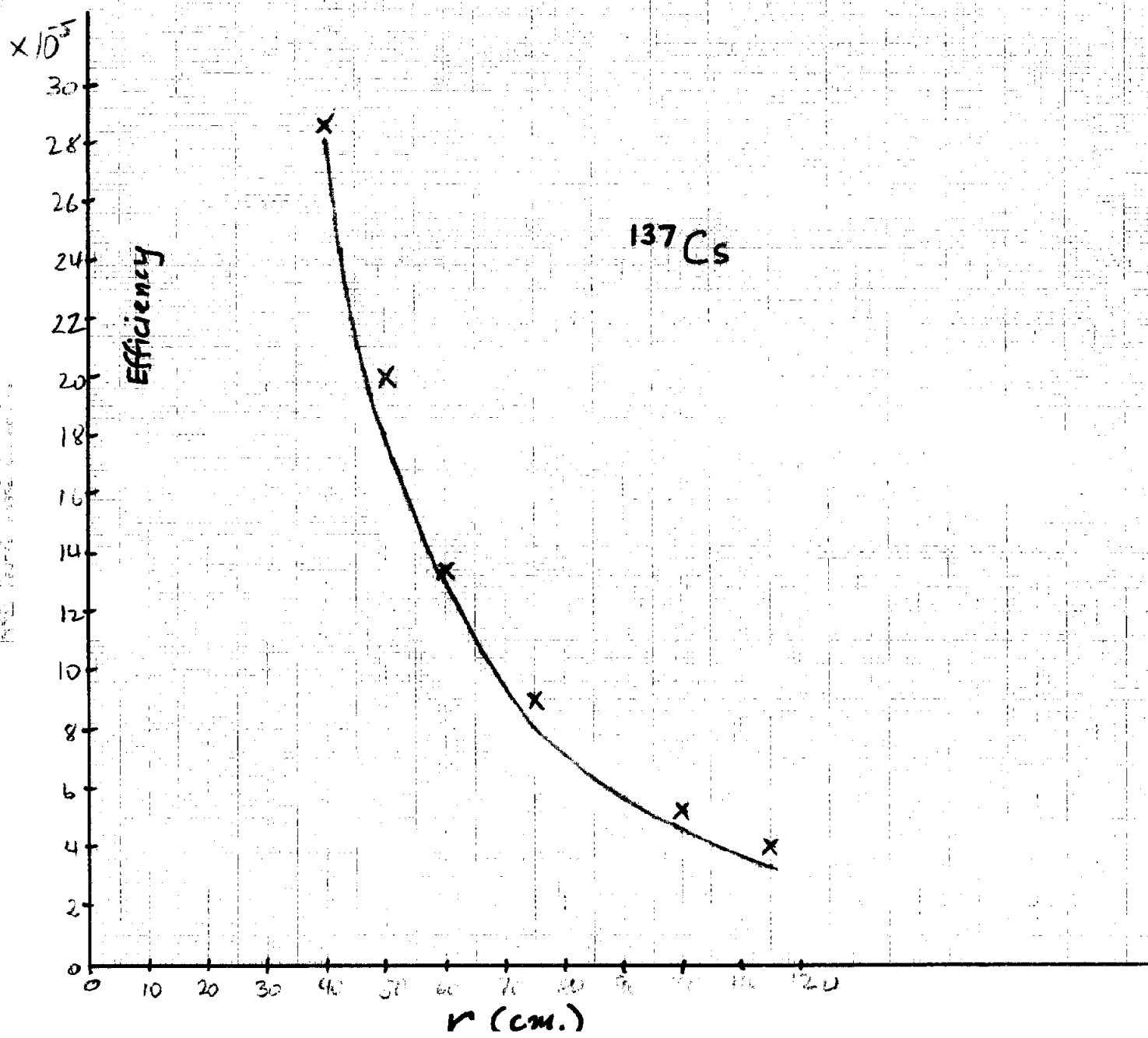


FIGURE 3

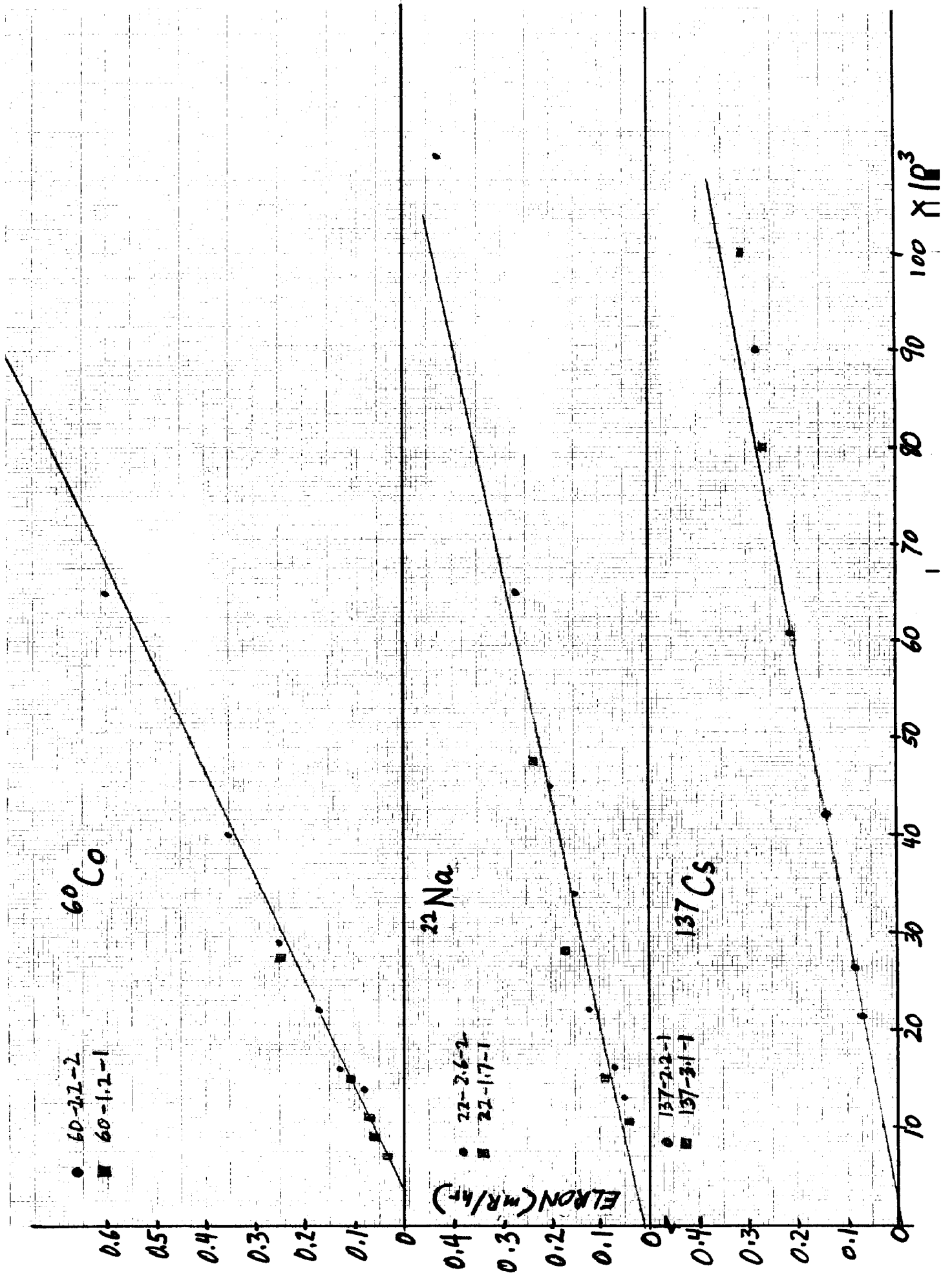


FIGURE 4

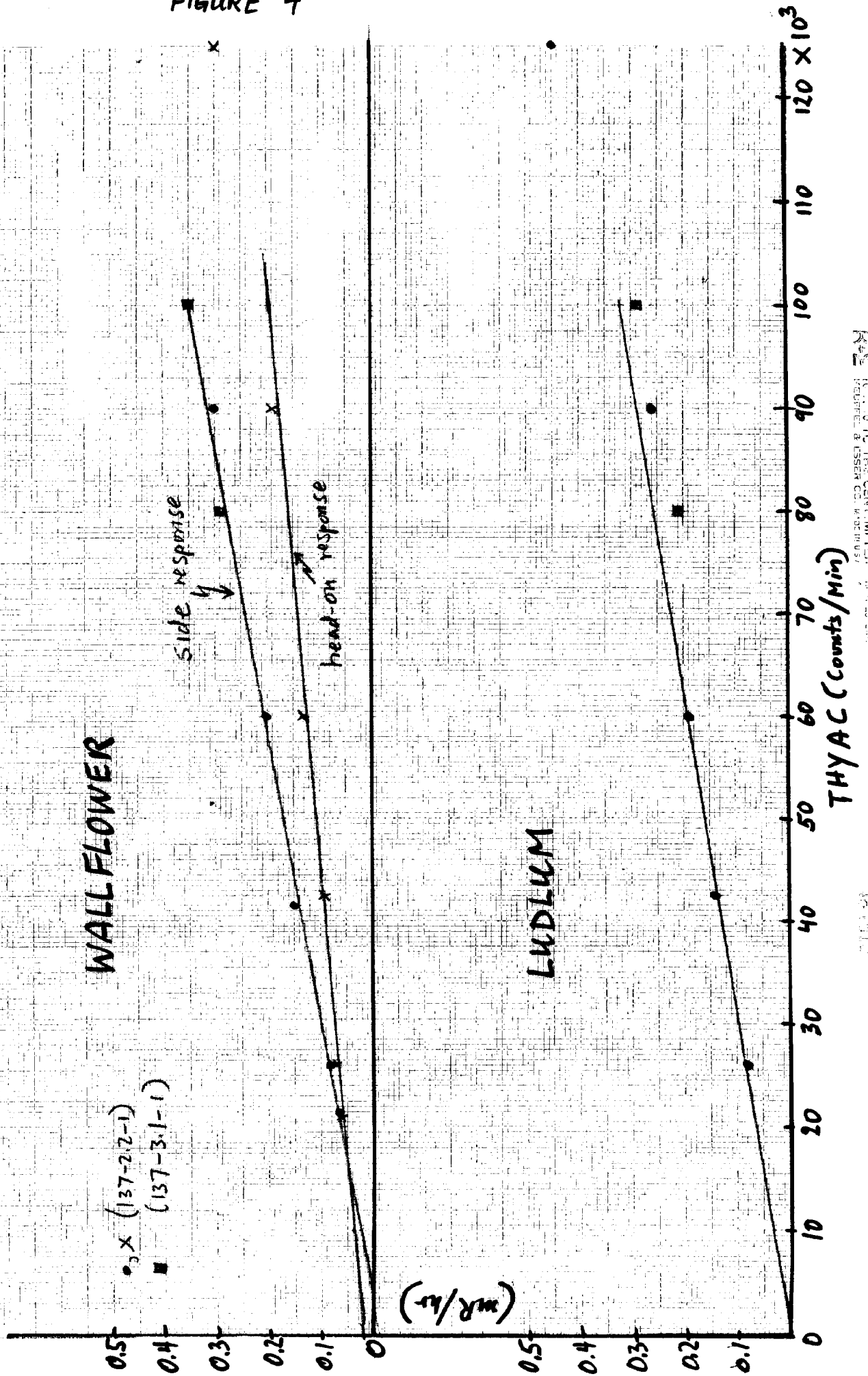


FIGURE 5

